

LA-UR-17-30388

Approved for public release; distribution is unlimited.

Title: Beta Emission and Bremsstrahlung

Author(s): Karpus, Peter Joseph

Intended for: DHS Gamma Spectroscopy Course

Issued: 2017-11-13

Disclaimer:

Los Alamos National Laboratory, an affirmative action/equal opportunity employer, is operated by the Los Alamos National Security, LLC for the National Nuclear Security Administration of the U.S. Department of Energy under contract DE-AC52-06NA25396. By approving this article, the publisher recognizes that the U.S. Government retains nonexclusive, royalty-free license to publish or reproduce the published form of this contribution, or to allow others to do so, for U.S. Government purposes. Los Alamos National Laboratory requests that the publisher identify this article as work performed under the auspices of the U.S. Department of Energy. Los Alamos National Laboratory strongly supports academic freedom and a researcher's right to publish; as an institution, however, the Laboratory does not endorse the viewpoint of a publication or guarantee its technical correctness.



Beta Emission & Bremsstrahlung

Pete Karpus

November 2017

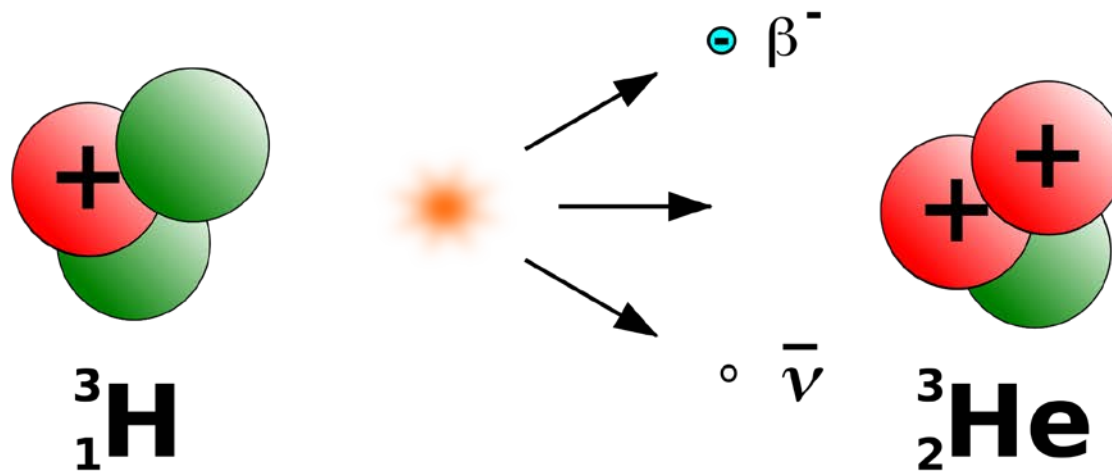
Introduction


- When a nucleus has too many protons or neutrons it may undergo beta decay
 - Too many neutrons $\rightarrow \beta^-$ decay
 - Too many protons $\rightarrow \beta^+$ decay
- β^- and β^+ particles are the same as electrons and positrons respectively
- β^+ particles quickly undergo pair annihilation but β^- particles will radiate a continuous range of photons as they decelerate in various media.

UNCLASSIFIED

Beta Decay

Here we see tritium decaying to He-3. A third particle given off in this reaction is called an anti-neutrino. It is undetectable by typical radiation/search detectors.



$E = mc^2$  **Mass-Energy difference of ${}^3\text{H}$ and ${}^3\text{He}$ in MeV*:**
 $2809.449895 - 2809.431302 = 0.018593$

This is the "endpoint energy of the emitted β particle"

* atomic masses

UNCLASSIFIED

“Pure” β^- Emitters

Nuclide	Half-Life	End Point Energy (MeV)
H-3	12.26y	0.0186
C-14	5730y	0.156
P-32	14.28d	1.71
P-33	24.4d	0.248
S-35	87.9d	0.167
Cl-36	3.08E+05y	0.714
Ca-45	165d	0.252
Ni-63	92y	0.067
Sr-90/Y-90	27.7y/64h	0.546/2.27
Tc-99	2.12E+05y	0.292
Pm-147	2.62y	0.224
Tl-204	3.81y	0.766

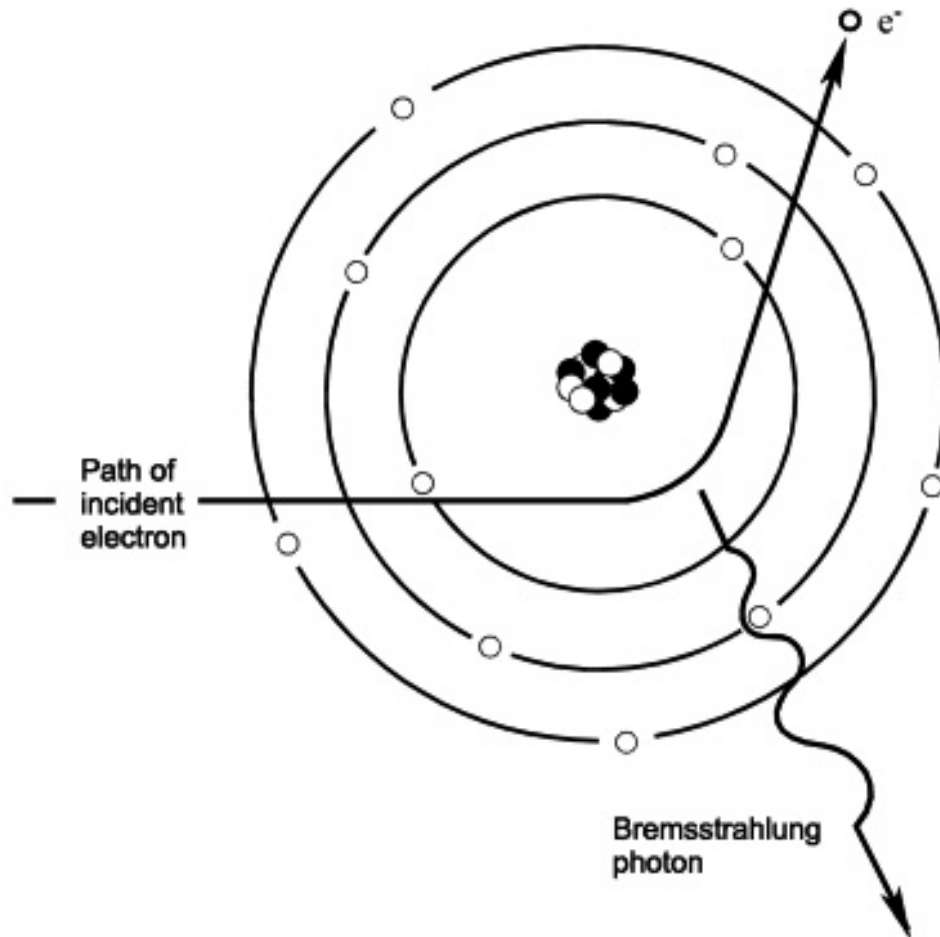
UNCLASSIFIED

Bremsstrahlung

When a free charged particle undergoes acceleration (either positive or negative) it radiates photons.

Free electrons slowed by the electromagnetic field of a nucleus emit photons in a continuous range of energies (up until some maximum or “endpoint”)

Bremsstrahlung is German for “braking radiation”



UNCLASSIFIED

β^- Energy Loss

- Collisional (produces no photons)
- Radiative:

$$-\frac{dE}{dx_r} = \frac{NEZ(Z+1)e^4}{137m_0^2c^4} \left(-\frac{4}{3} + 4\ln \frac{2E}{m_0c^2} \right)$$

N: number density of absorber atoms

E: β^- energy

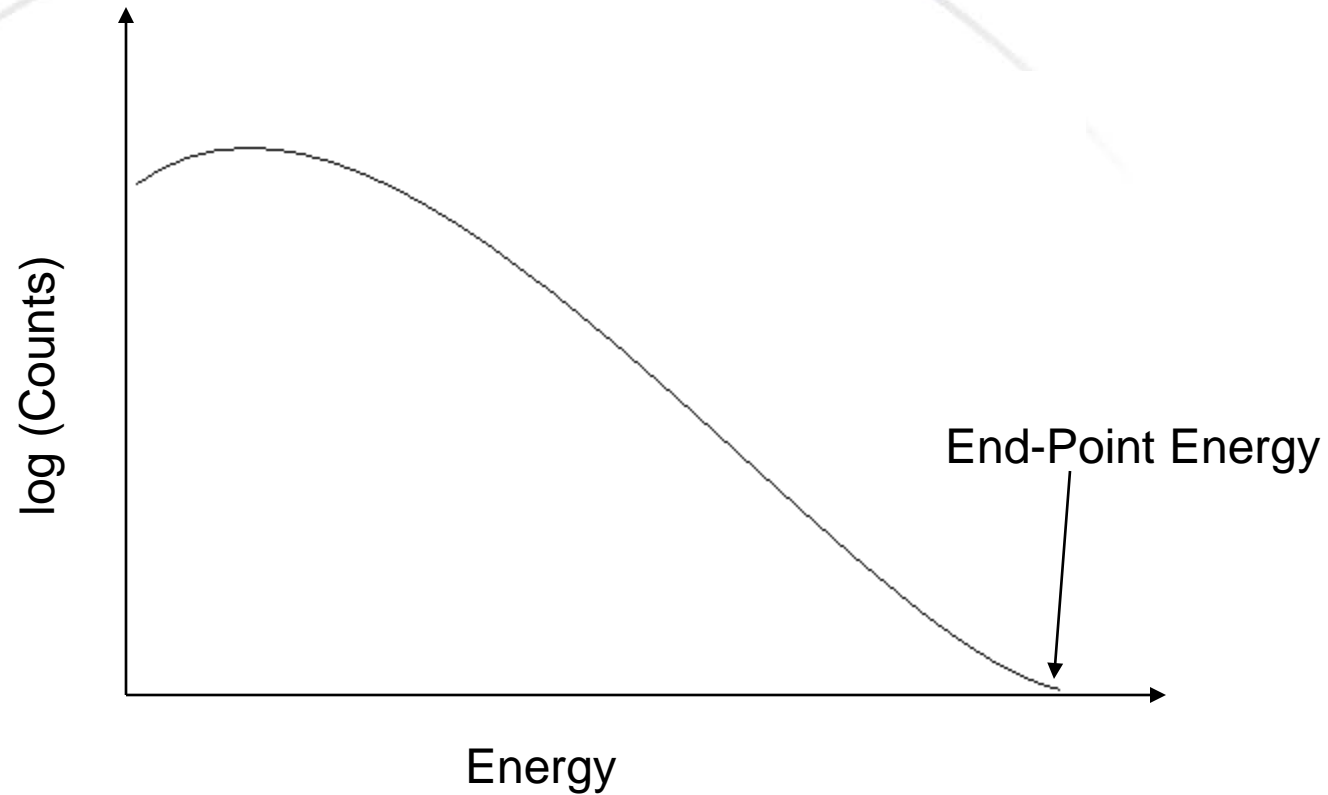
Z: absorber atomic number

e: electron charge

m_0 : electron rest mass

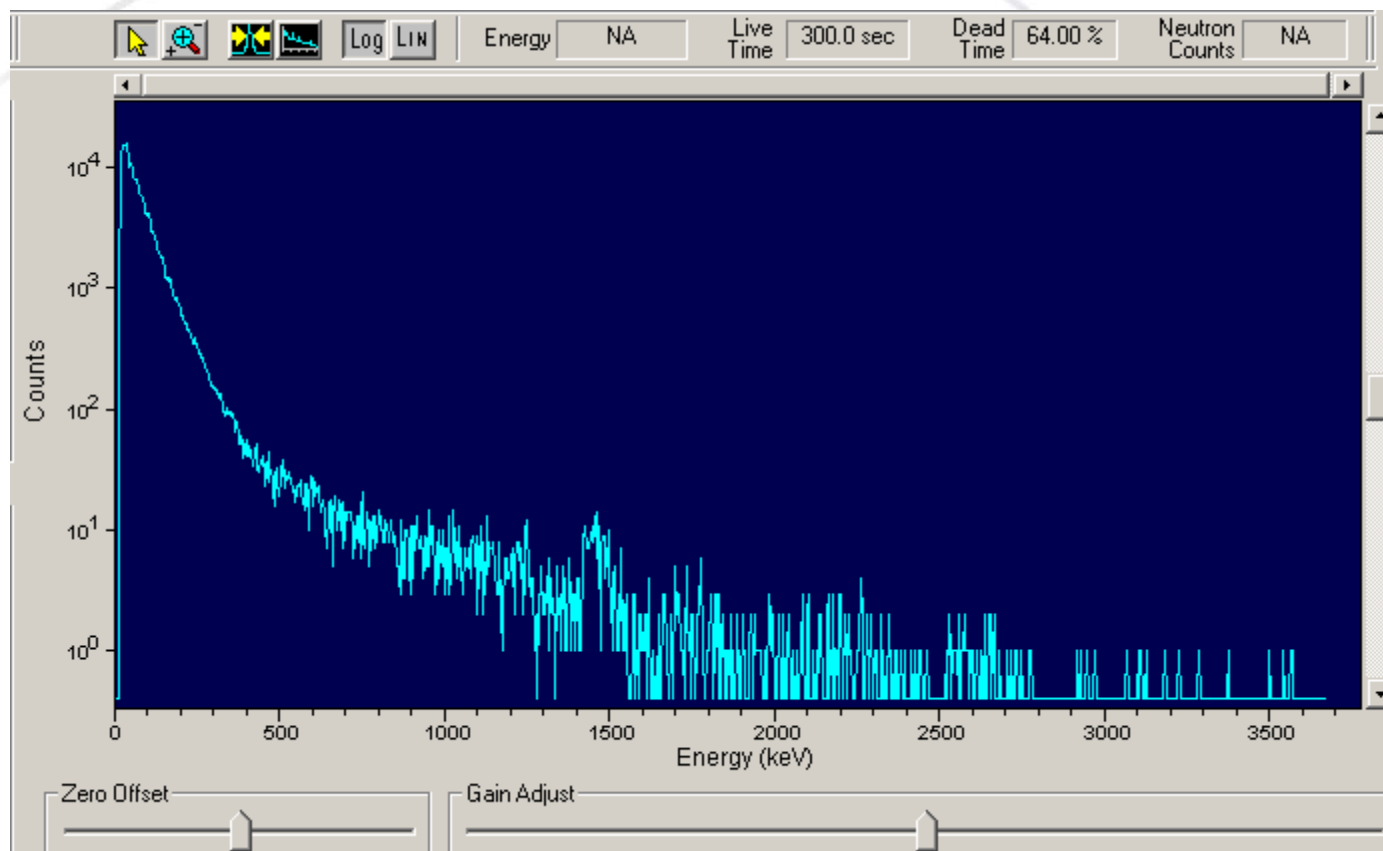
UNCLASSIFIED

Idealized β^- Spectrum



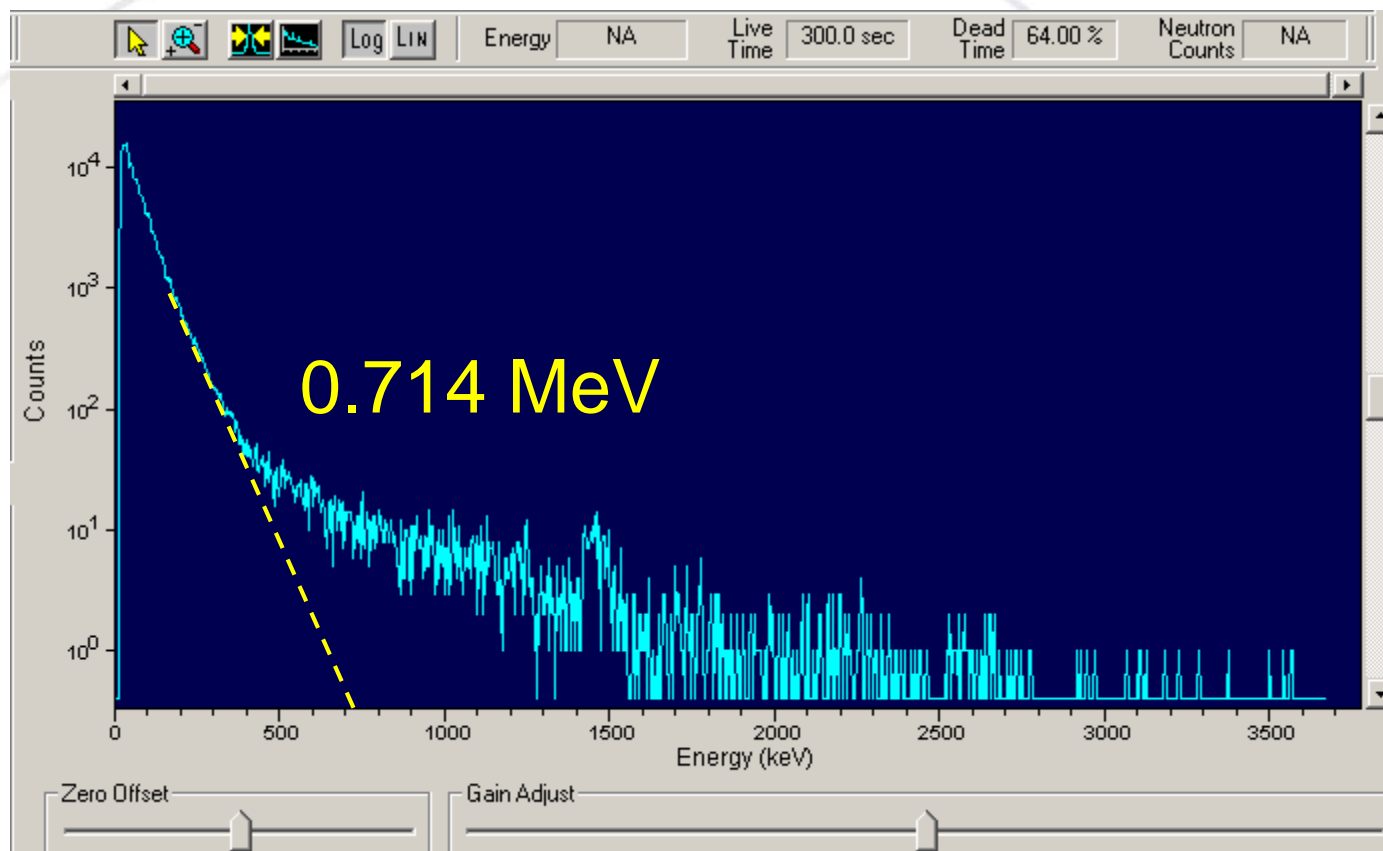
UNCLASSIFIED

Bremsstrahlung from Cl-36



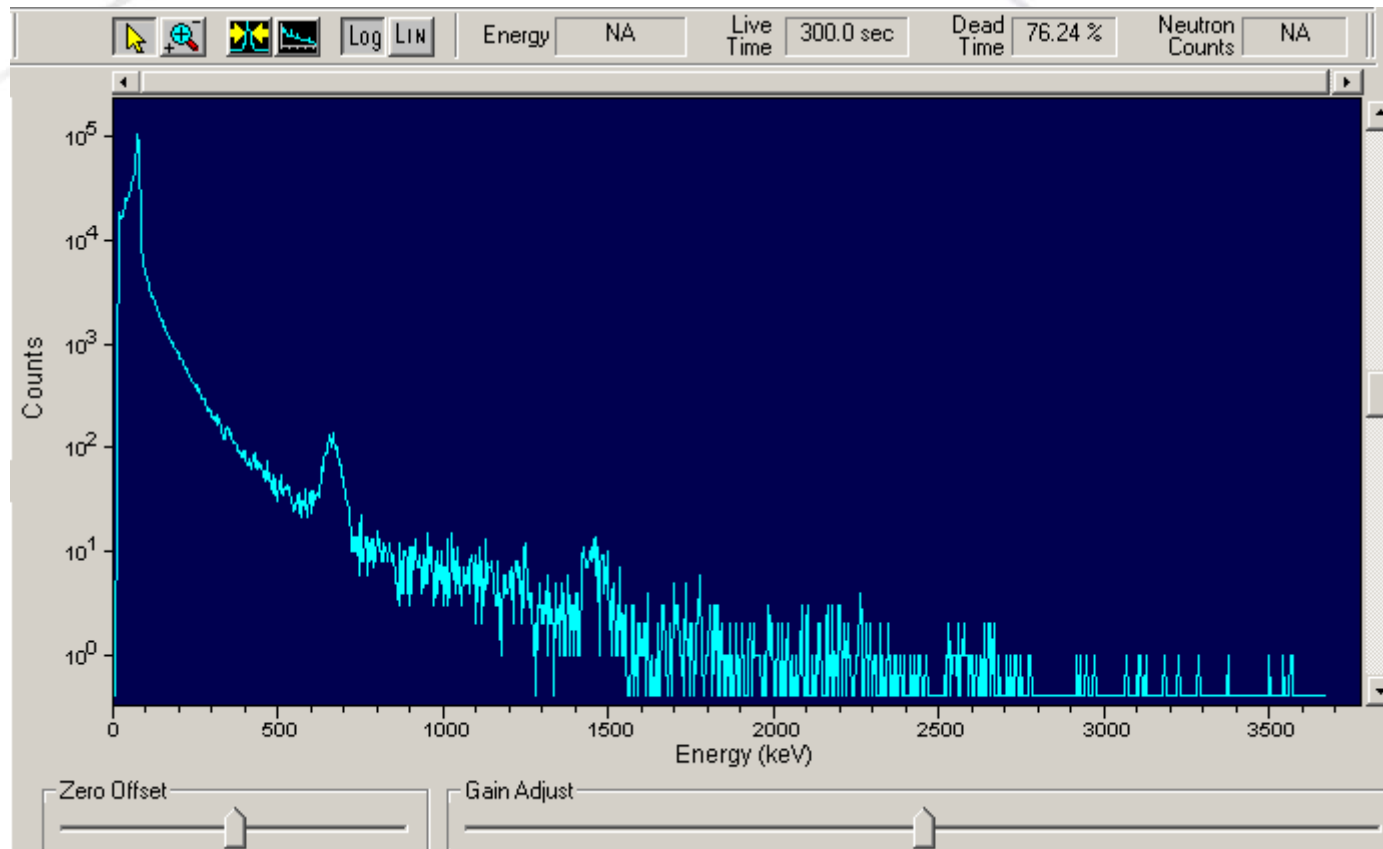
UNCLASSIFIED

Bremsstrahlung from Cl-36



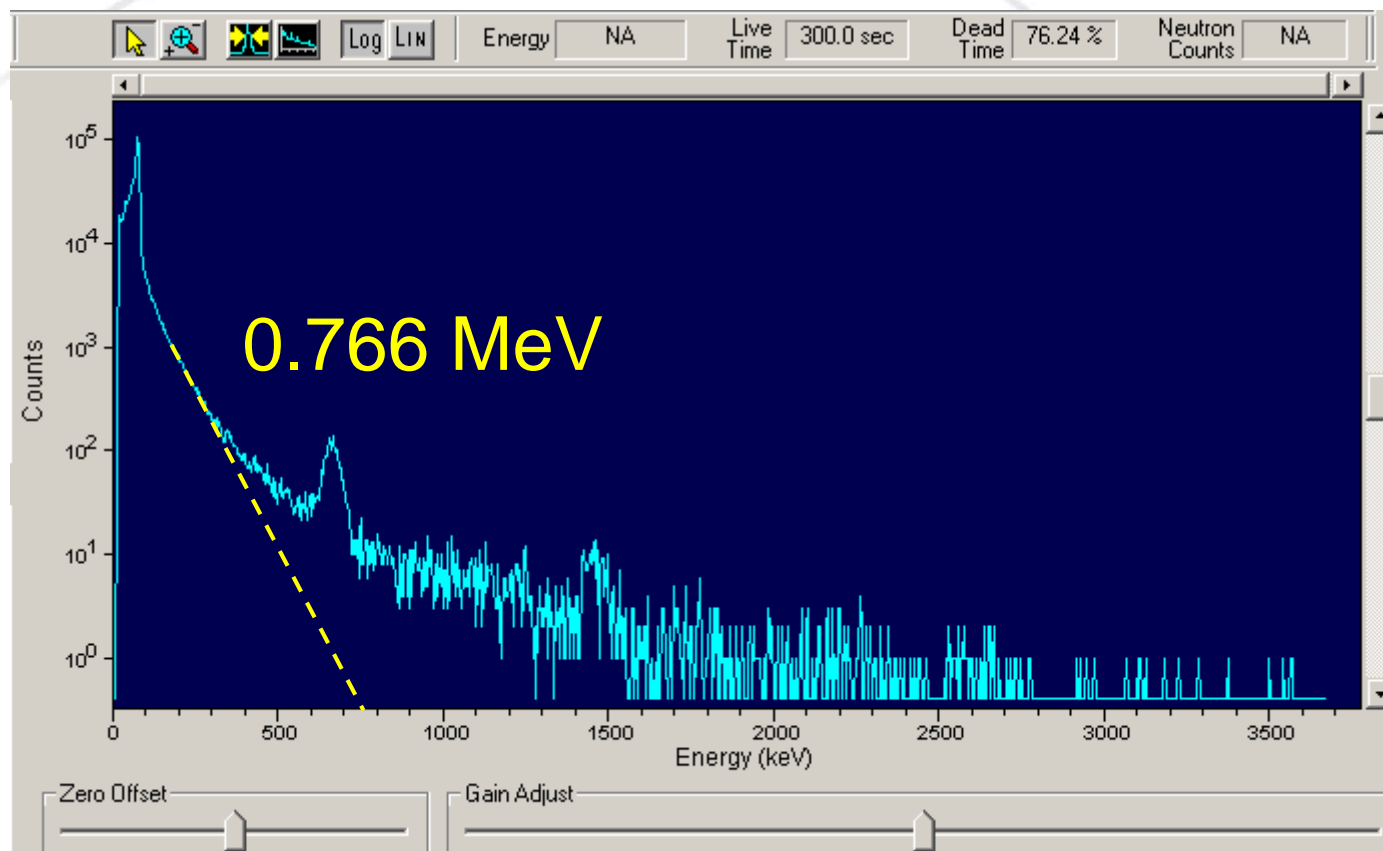
UNCLASSIFIED

Tl-204 Bremsstrahlung + Cs-137



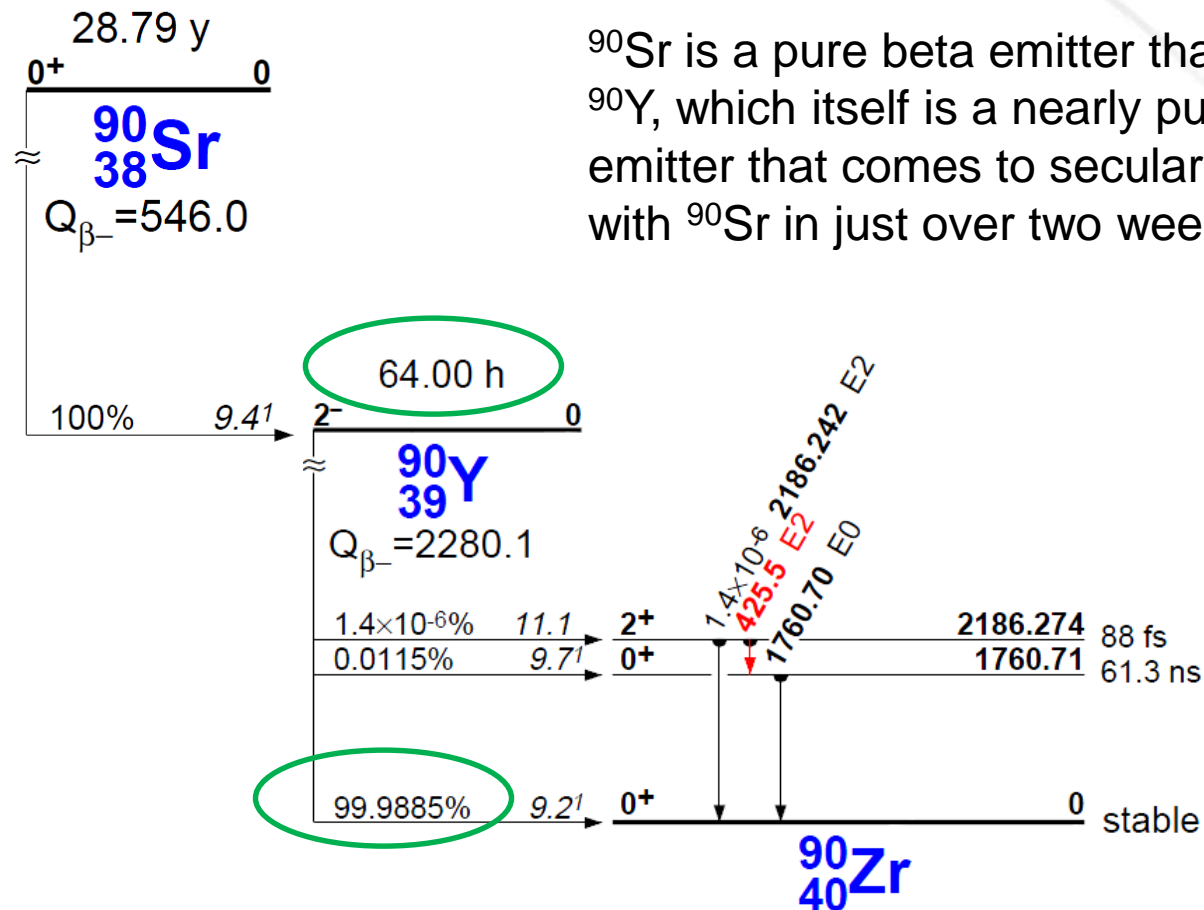
UNCLASSIFIED

TI-204 Bremsstrahlung + Cs-137



UNCLASSIFIED

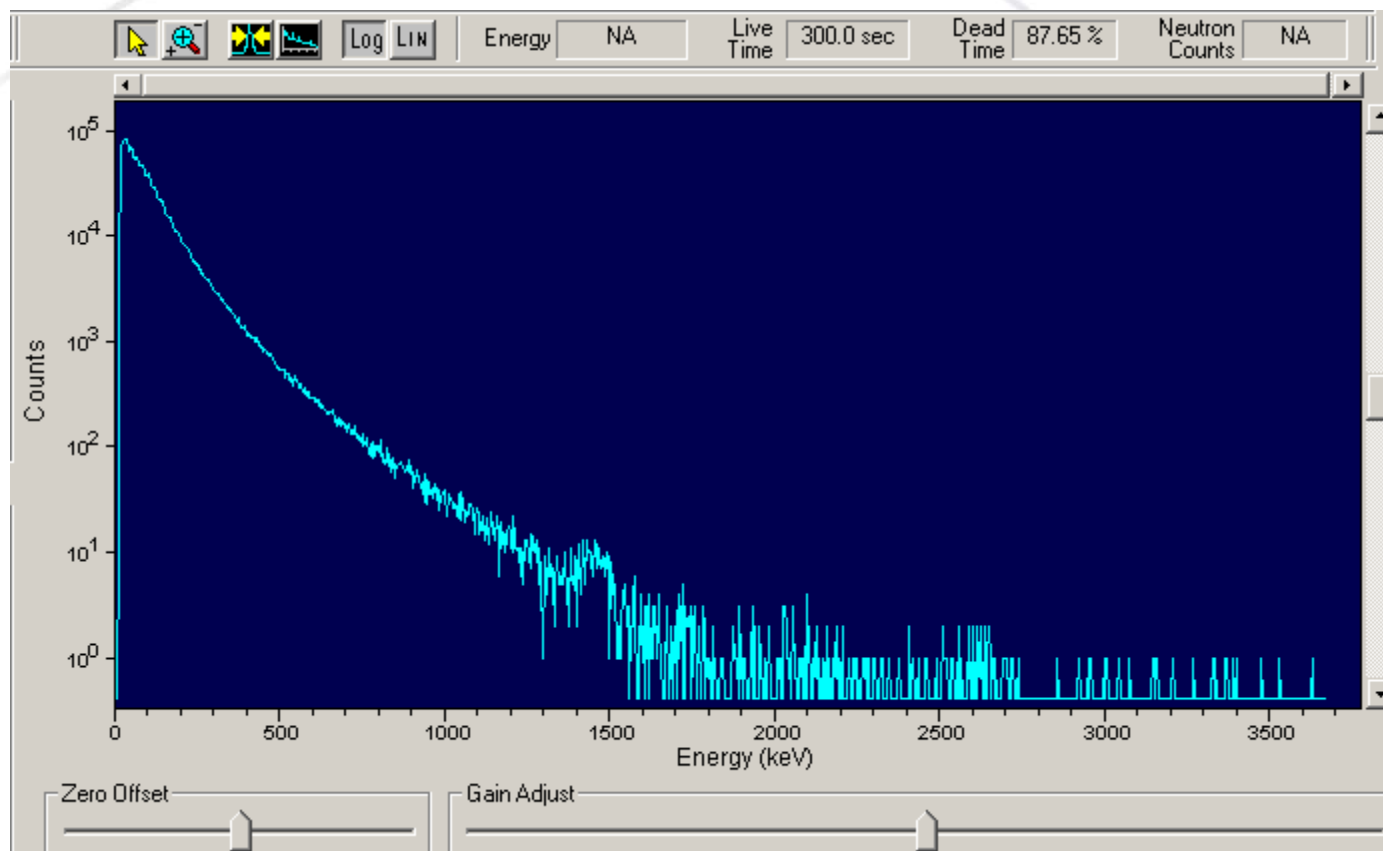
$^{90}\text{Sr} / ^{90}\text{Y}$ Level Scheme



^{90}Sr is a pure beta emitter that decays to ^{90}Y , which itself is a nearly pure beta emitter that comes to secular equilibrium with ^{90}Sr in just over two weeks.

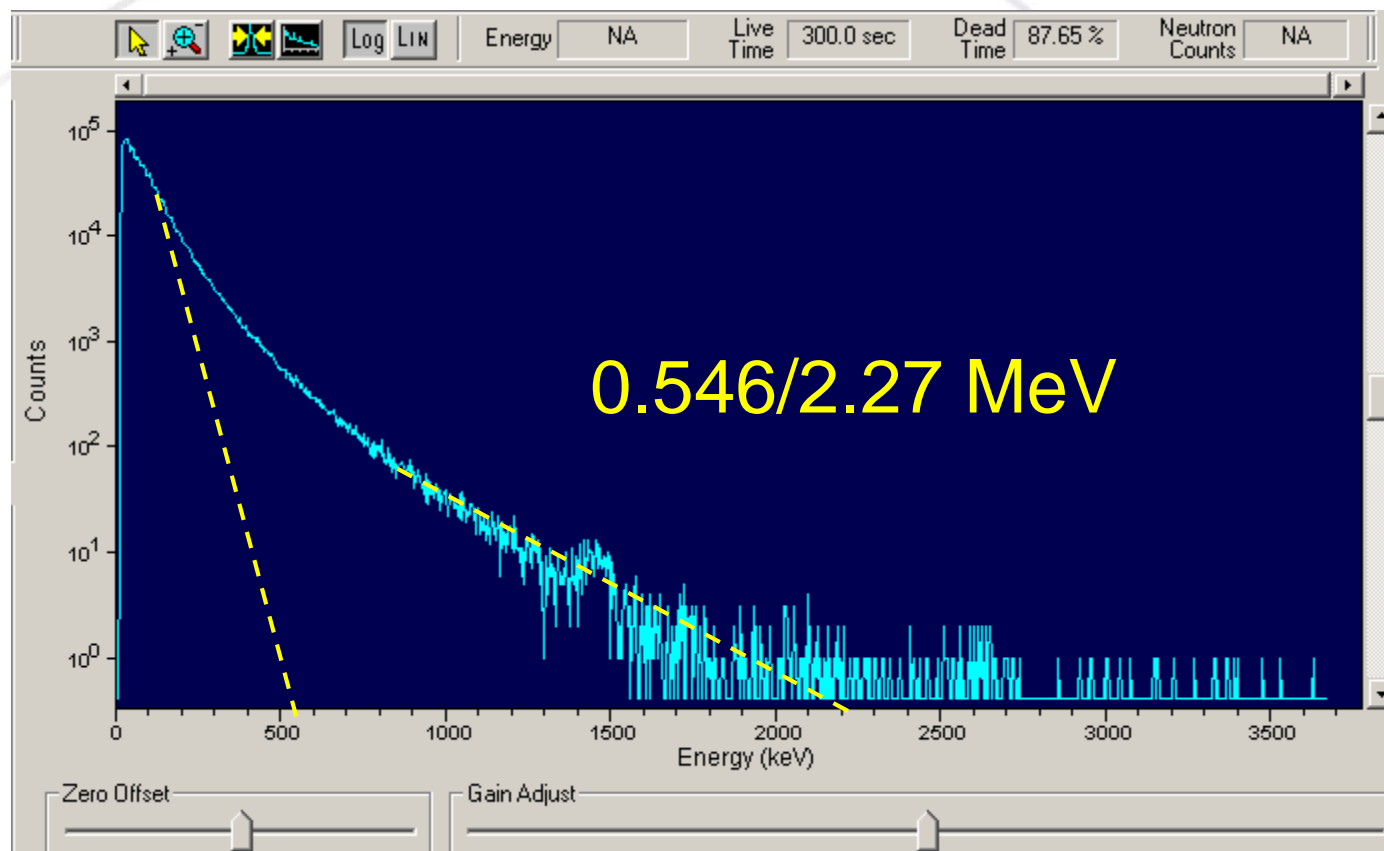
UNCLASSIFIED

Bremsstrahlung from Sr/Y-90



UNCLASSIFIED

Bremsstrahlung Sr/Y-90



UNCLASSIFIED

Summary

- Bremsstrahlung is continuous radiation produced by beta particles decelerating in matter
- Different beta emitters have different endpoint energies
- High-energy betas interacting with high-Z materials will more likely produce bremsstrahlung
- Depending on the data, sometimes all you can say is that a beta emitter is present

UNCLASSIFIED